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Refractory Material for Cement Rotary Kilns.

By J. FAUNER.

THE problem of lining the cement rotary kiln has not yet been entirely satisfactorily solved. The capacity and uninterrupted running of the kiln are limited by the rapid deterioration of the lining material, and to the cost of repair must be added the loss due to the kiln being out of action.

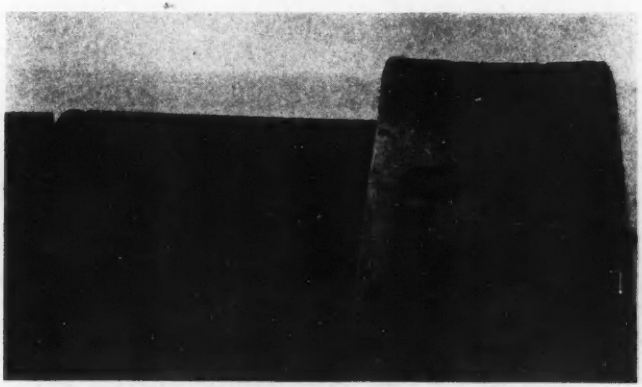

Fig. 1.

The causes of the destruction of the kiln lining can be classified under the three headings: (1) Mechanical effects; (2) Thermal changes; and (3) Chemical reactions at high temperatures. Generally all three effects work together. In many cases where the lining blocks travel to the works by rail or water they are already damaged on arrival. This can be avoided by good packing and by careful handling during loading and unloading; attention to

these details is well worth while, even though the costs be somewhat increased thereby. The blocks should not be stacked on the ground, but on a wooden platform to protect them from the moisture of the earth. They must not be stored in the open, but must be protected from rain and frost.

It must be ensured that the blocks used for lining the kiln have not been damaged at the edges. If blocks which have been split in two are built into the kiln long life cannot be expected even from the best material. This is especially the case in the clinkering zone, owing to the high temperature and the considerable abrasion by the clinker.

Mechanical Wear.

One of the chief causes of the rapid destruction of lining blocks is the heavy wear due to abrasion by the raw meal and clinker. Fig. 1 gives a comparison of a block from a dry-process kiln and an unused block. In less than four months the block has been worn down from the original 9in. to 3in. The wear

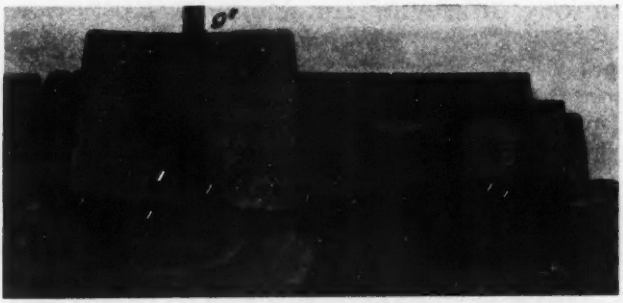

Fig. 2.

of the blocks in the calcining zone, although less pronounced, is still considerable. In Fig. 2 is compared the mechanical wear on blocks from the clinkering and calcining zones during the same period of working. The 9in. block has been reduced to 3in. in the clinkering zone, and the 6in. block to 4in. in the calcining zone. It is obvious from this that the natural hardness of the stone has a great influence on its life. Adequate hardness is attained by the choice of a hard-grained material and intense initial burning. It is for this reason that corundum and similar hard materials are employed. The hardness of kiln lining blocks is tested by means of the Boehme or Bauschinger grinding wheel. The test is carried out under 8½ lb. per sq. in. pressure over a path of 665 yds., using twenty lots of 20 g. Naxo emery No. 3. The result is expressed as the loss in weight in grammes, or in grammes divided by the weight per cubic centimetre.

Thermal Effects.

A further cause of deterioration of the refractory lining of the rotary kiln is the thermal expansion of the material and its sensitivity to changes of temperature. The lining blocks increase in volume on heating and decrease

on cooling. If subjected to sudden heating or cooling, strains are set up which may result in the splitting of the blocks. In Fig. 3 are shown the temperatures attained in the kiln, together with those of the lining and iron shell. It is seen that near the kiln mouth the temperature is very high and rises rapidly, its subsequent fall being also very rapid. Practical experience has shown that the

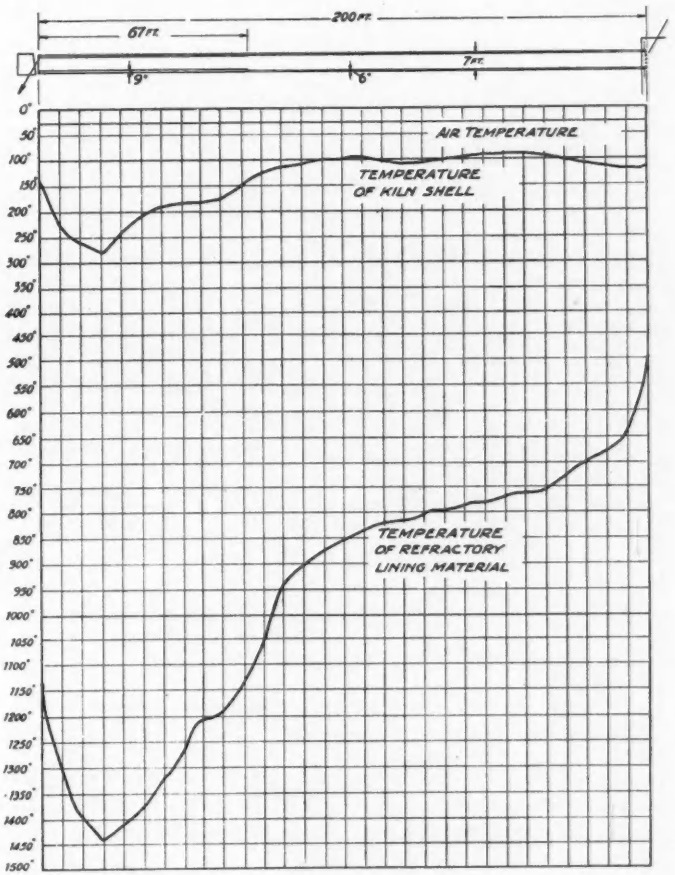

Fig. 3.

refractory bricks are most sensitive to temperature change at a dark red heat, i.e., about 650 deg. C. Since, however, in normal running the temperature of the various zones of the kiln at most varies only very slightly, damage to the lining as a result of sudden changes of temperature is relatively slight. Endell has recently shown, both in the laboratory and in practice, that the lining blocks

of high alumina content in common use are relatively insensitive to temperature change. If the material used for the blocks is satisfactorily homogeneous and stored for a long period, and if a proportion of kaolin is added to the clay used for binding and the blocks are well burnt, a dense brick can be produced which is not sensitive to changes of temperature.

Fig. 4 gives the thermal expansion of a number of refractory materials. Sillimanite is seen to have a sudden expansion at about 1,400 deg. C., while the other materials, and especially diaspore, expand uniformly. In order to reduce the thermal conductivity and sensitivity to temperature changes, works in North America increase the porosity as much as is possible without lowering the mechanical strength. The resulting slight softening under compression at

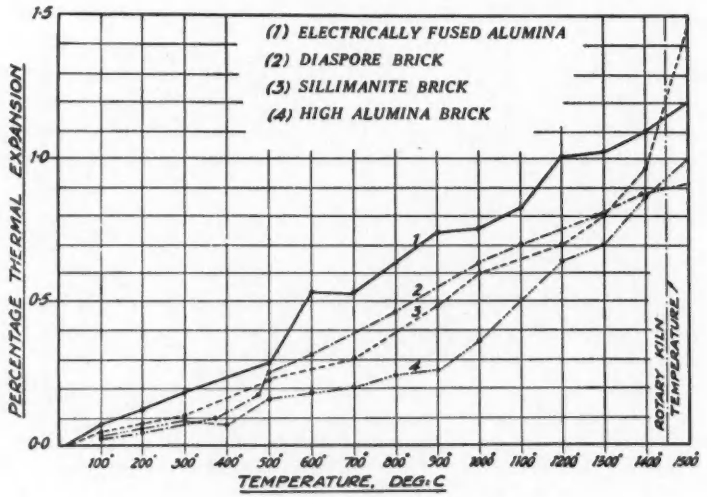

Fig. 4.

high temperature is unimportant under rotary kiln conditions. Since it has been stated that at a red heat bauxite withstands temperature changes less well than diaspore, the two were experimentally compared up to 1,000 deg. C. Actually the conductivity and expansion of bauxite between 200 and 800 deg. C. are higher than for diaspore (Fig. 5), but this can easily be corrected by suitably adjusting the particle grading.

To summarise, it may be stated that in normal rotary kiln practice the temperature changes are at most only slight, and exert no ill effect on the relatively insensitive high alumina blocks. The real danger is met on starting the kiln or on rapid cooling due to stoppages. If the utmost care is not taken in these circumstances the blocks may split, with the result that single blocks may drop out, leading to the falling in of an entire ring of blocks. In starting and

stopping the cold air must be at once cut off, and in the wet process the slurry feed must be reduced or entirely stopped.

The extent to which thermal expansion endangers the life of the kiln lining is not yet entirely elucidated. As already mentioned, the structure and manner of preparation of the lining blocks plays a part in addition to the nature of the raw refractories used for the bricks; bricks of different thermal expansion can be prepared from the same raw materials. The expansion between room temperature and 1,500 deg. C. should not exceed 1.2 per cent.

Chemical Attack.

Chemical attack occurs almost entirely at the higher temperatures and is more pronounced as the clinkering zone is approached. In the cooler zone, at about 400 deg. C., under strongly reducing conditions, there is a reaction

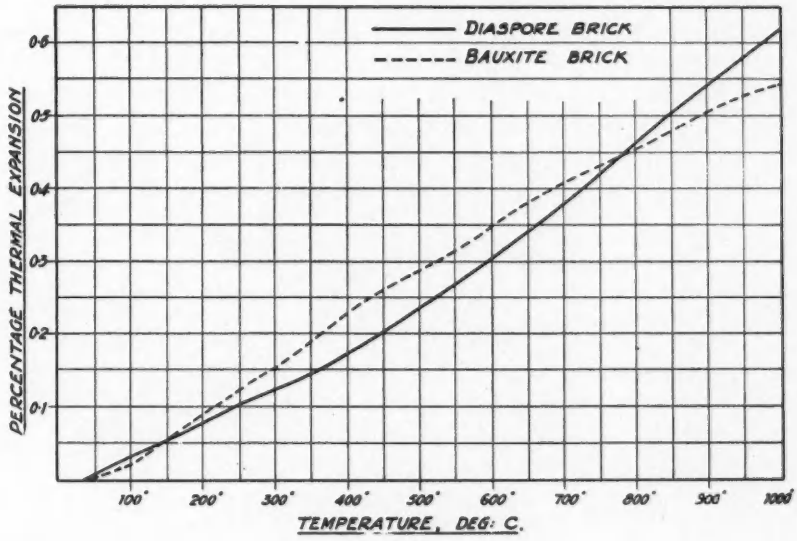

Fig. 5.

between the carbon monoxide and the iron in the lining blocks. A strongly reducing flame has a more important effect in the hottest zone, in that SiO_2 and alkalis are distilled off and condense again in the cooler zone. There is thus an increase in the proportion of alkalis in the cooler parts which favours the formation of slag. Other disadvantages of a strongly reducing flame are the loss of fuel and the undesirable light colour of the resulting cement.

Slag formation is contributed to by the fluxing constituents of the fuel and of the refractory material itself, together with the raw meal and clinker dust. Most important are the oxides of iron and of manganese and the alkalis. Fluorspar,

which often occurs in or is added to the raw meal, has a strong destructive action ; it attacks the lining even at 1,000 deg. C.

At the temperature of the kiln the surface of the lining material softens somewhat and a certain amount of raw meal or clinker dust adheres to it. The proportion of flux at the surface is thus increased, the melting point is lowered, and a glassy dark-coloured layer of slag is formed. At first this has a protective action on bricks of good structure. Later, however, owing to abrasion by the raw meal, and more especially by the clinker, the surface of the brick is again exposed. With refractory bricks of low melting point and poor structure, and with raw materials or fuel rich in fluxes, the wear of the lining due to slag formation and abrasion proceeds very rapidly : a brick of this kind is depicted in Fig. 6.

Bricks with a thick layer of slag on the surface are very sensitive to temperature changes. On sudden heating or cooling the slag splits from the brick and exposes its interior, resulting in rapid destruction.

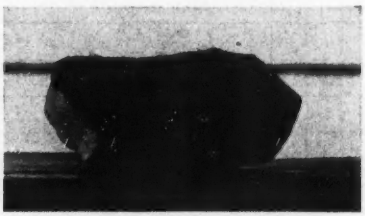

Fig. 6.

The lime of the raw materials is in itself a powerful flux. As already pointed out, the surface of the lining becomes somewhat soft and takes up clinker dust and raw meal. To demonstrate the fluxing action of the CaO a brick of the following composition was mixed with CaO and burnt in a coal-fired furnace :— Al_2O_3 72.63, Fe_2O_3 2.06, SiO_2 19.62, TiO_2 3.30, CaO 0.68, alkalis 1.72, MgO trace.

The results were as follows :—

Adding 0 per cent. CaO	melting point 1,830 deg. C.
Adding 5 per cent. CaO	melting point 1,580 deg. C.
Adding 10 per cent. CaO	melting point 1,460 deg. C.
Adding 15 per cent. CaO	melting point 1,410 deg. C.
Adding 20 per cent. CaO	melting point 1,320 deg. C.
Adding 30 per cent. CaO	melting point 1,275 deg. C.

This experiment clearly shows the destructive action of CaO on the refractory material. In kiln practice there are on the one hand destructive agencies such as iron and manganese oxides, flue dust and alkalis, and on the other hand protective agencies, such as the adhesion of clinker dust and raw meal to the softened surface, protecting it from the direct action of the flame.

Fig. 7 shows the surface of a lining block under the microscope. O is the surface ; Z is fused cement, with fine pores, enriched with Al_2O_3 and CaO ; K is a particle which has resisted the attack of the slag ; the channel from Sch-Fe to the particle K is a bubble filled with slag enriched with iron. The above discussion shows that the chief factor in the destruction of the kiln lining is slag formation combined with abrasion. The more the bricks resist abrasion the higher their melting point, and the higher their Al_2O_3 content (or the lower their content of fluxes) so much the more will they be difficult to wear down, and they will offer a greater resistance to the formation of slag.

The older method of lining the rotary kiln is to join the blocks with mortar of the same composition (but rather leaner, so that shrinkage is small), with only a small space between the blocks. For some time the method of building

Fig. 7.

the blocks into the kiln without mortar has been adopted, principally in America and Asia. This method is rapid, cheap and has given the best results. The lining blocks must, of course, fit the iron shell of the kiln, or the result will be unsatisfactory. The blocks are built half-way up the kiln, fixed in position by inserting a transom, and the kiln is then rotated through 180 deg. The second half of the lining is then built in, the supports are removed, and any larger interstices are mortared. The method of carrying out the work is clearly seen from Fig. 8. When the lining is completed it is entirely covered with thin cement paste and allowed to dry. The use of special cements is unnecessary.

For dry process kilns the thickness of the blocks is 9in. in the clinkering zone and 6in. elsewhere. For wet process kilns it is best to adopt 8in. throughout. If very hard raw materials are used these figures may be somewhat increased. Fused high alumina blocks should, however, be somewhat smaller, and the values 4, 5 and 6in. should replace 6, 8 and 9in.; this enables the output to be increased.

In the earlier days of the rotary kiln neutral stone of some 42 per cent. Al_2O_3 content was used for lining. The raw material was very carefully prepared, pressed, repressed and burnt at a high temperature. The raw material was the so-called pottery clay of Wildstein (Czecho-Slovakia). This was partly burnt to chamotte and coarsely ground. The fine chamotte meal was removed by sieving and the coarse material was mixed with the same clay as a binder. The fine meal was not used, because it makes the bricks dense and susceptible

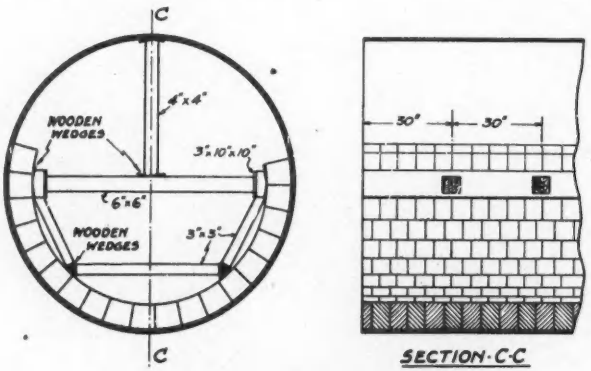

Fig. 8.—Method of Dry-lining Kiln.

to temperature changes. To prevent shrinkage of the blocks when built into the kiln they were burnt to Seger cone 14 (1,410 deg. C.). The following results were obtained with a brick of this type: It squatted at Seger cone 34 (1,750 deg. C.), began to soften at cone 7 (1,230 deg.), and shrunk together at cone 16 (1,460 deg.). The percentage chemical analysis was: Loss on ignition 0.36, SiO_2 55.07, Al_2O_3 41.70, Fe_2O_3 1.84, CaO 0.49, MgO 0.12, TiO_2 0.40, alkalis by difference.

The refractory quality, resistance to abrasion and stability under changes of temperature were extremely good, and bricks of this type are even now used in the calcining zone with excellent results.

Valeur suggested in 1900 lining the kiln with Portland cement, with the object of avoiding the rapid deterioration of the lining. This process is in successful use at the present day in cases of small kilns which do not work continuously. According to the German patent 134820, clinker of 2 mm. to 20 mm. diameter is mixed with cement, and lining blocks are formed from the mixture. After lining the kiln the interstices are filled with thin cement paste. The method

is rapid and cheap, and can be used for small kilns, especially when the cement works is distant from a supply of refractory materials. For continuous working and for kilns of high output the process is not suitable.

In view of the rapid deterioration of brick containing 42 per cent. Al_2O_3 highly basic materials received consideration. By increasing the alumina content the brick becomes more refractory, can be burnt at a higher temperature—thus becoming stronger mechanically—and gives very little or no after-shrinkage in the rotary kiln. The first attempts were made with bauxite, which was burnt and granulated, mixed with refractory clay (kaolin), prepared in the usual way and burnt at Seger cone 14. The results of tests of a brick so obtained are as follows :—It squatted at Seger cone 36 (1,790 deg. C.), began to soften at cone 12 (1,350 deg.) and shrunk together at cone 16–17 (1,470 deg.). The percentage chemical analysis was :—Loss on ignition 0.05, SiO_2 25.35, Al_2O_3 72.05, Fe_2O_3 1.96, CaO 0.35, MgO 0.12, TiO_2 nil, and alkalis by difference. Bauxite brick is somewhat sensitive to temperature changes, but this can easily be counteracted by using coarser grading, removing the fine meal and adding a certain amount of kaolin as a binder. Bauxite is unfortunately generally accompanied by iron and pure bauxite is very dear. Accordingly bauxite has frequently been replaced by natural corundum with success. Another material that has been successfully used is alundum, obtained by the thermit process. Bricks of these materials have an alumina content of 62–66 per cent., and are characterised by their resistance to temperature changes and by their hardness.

Recently, particularly in North America, diaspore has been used with good success as the basis of lining blocks, in view of its being readily procured. The first attempts to use diaspore were made less than ten years ago, but it has already made considerable headway. It is found in the South of the United States in large quantities, and blocks weighing a ton are frequently met. The material is selected and mixed with bauxite. The granular material is burnt to Seger cone 18 (1,500 deg .C.), passed two or three times through a clay mill, and pressed almost dry. The resulting bricks are burnt to Seger cone 14 (1,410 deg.), when they show a very slight after-shrinkage in the rotary kiln. After a second burning at 1,400 deg. C. this amounts to 0.52 per cent. The porosity of the diaspore brick investigated was noteworthy ; it amounted to 25–36 per cent. This results in the formation of a protective surface layer of cement which prevents the rapid abrasion of the brick. Further, highly porous bricks are less susceptible to temperature changes. The following are the results of tests of a diaspore brick intended for use in the clinkering zone :—Squatted at Seger cone 36–37 (1,810 deg.), began to soften at cone 11–12 (1,340 deg.) and shrunk together at cone 17 (1,480 deg.). The percentage chemical analysis was :—Loss on ignition 0.05, SiO_2 19.60, Al_2O_3 72.63, Fe_2O_3 2.20, CaO 0.66, MgO 0.04, TiO_2 3.45, K_2O 0.60, Na_2O 1.10.

The diaspore contained considerable quantities of titanium, and the iron content is also notable. Notwithstanding this the bricks are snow-white after burning.

A material which almost eliminates kiln lining difficulties is obtained from fused alumina with about 20 per cent. silica and marketed as Corhart Electrocast. The raw material is bauxite or diaspore which is fused with a certain amount of carbon in an electric furnace and poured directly into moulds. The moulds must have the exact dimensions of the bricks, since the hardness of these prevents later adjustment. A lining of this material has four to six times the life of other materials. The results of tests are :—Hardness 9–10, porosity 0.8 per cent., squatted at Seger cone 35 (1,770 deg.), SiO_2 25.26, Al_2O_3 71.65 and fluxing constituents 3.09 per cent.

The above material is for use in the clinkering zone. In the calcining zone the lining is less subjected to thermal and chemical stress, and in general well-burnt blocks of 42 per cent. alumina content are suitable, e.g., the above-mentioned aluminous brick. Blocks with a basis of bauxite, corundum, diaspore, etc., also give good results. Investigation of the bricks generally used in North American works shows that they all contain up to 40 per cent. Al_2O_3. A brick of this type gave the following test results : Squatted at Seger cone 34 (1,750 deg.), incipient softening at cone 8 (1,250 deg.), and shrinkage at cone 15–16 (1,450 deg.). Percentage analysis : loss on ignition 0.04, SiO_2 56.05, Al_2O_3 40.07, Fe_2O_3 2.07, CaO 0.40, MgO 0.04, Na_2O 0.66, K_2O 0.30.

Bricks of lower alumina content are also successfully used in the calcining zone, provided the structure of the brick and the rotary kiln burning are satisfactory. The following details relate to such a brick which has lasted for three years in the calcining zone in a kiln in Asia : Squats at Seger cone 33 (1,730 deg.) ; percentage analysis—loss on ignition nil, SiO_2 72.90, Al_2O_3 24.19, Fe_2O_3 1.68, CaO 0.20, MgO trace, alkalis by difference.

After the three years working this brick had a porosity of 8 per cent. and was not vitrefied internally. The maximum grain size was 5 mm. and the grains were well bedded in the ground-mass. To summarise, any good refractory material can be used in the calcining zone, provided that it is well burnt, is not very susceptible to temperature changes and is not of acidic nature.

Bricks for the clinkering zone should not squat below Seger cone 34–35 (1,760 deg. C.) and for the calcining zone cone 33 (1,730 deg.).

Structure of Refractory Lining Blocks.

Macroscopic and microscopic examination gives important evidence regarding the quality of refractory bricks. From each 200 clinkering zone blocks and each 500 calcining zone blocks are taken two samples, one of which is sawn through the breadth and the other through the height. These can later be ground and used as mortar for the lining.

Macroscopic examination of the sections will show up bad working of the refractory raw materials : such as uneven distribution of the particles of refractory ; bricks prepared from material contaminated with petroleum or oil break up on burning ; material worked too wet shows segregation of the refractory particles into the interior or towards the base, while only the finer particles, and possibly

only the binding clay, are found near the surface. Similarly materials containing too much of the refractory are easily detected ; this results in a dense stone which is sensitive to temperature changes. The form and size of the refractory granules afford information as to future behaviour. If the granules are too large an excess of binding clay is necessary, which is undesirable. The use of very small grains or meal leads to rapid vitrefaction in the kiln. The best grain size is 0.5 to 5 mm. diameter. The grains should be angular and well burnt, and the section should be free from cracks and not vitrefied. Examination with a lens will show the nature of the union between the refractory grains and the clay, as well as the size and distribution of the voids. Very porous bricks in which the pores are not uniformly distributed as fine pores, but are irregular and joined by channels, are unsatisfactory ; the slag rapidly penetrates such bricks (Fig. 7) and they are rapidly corroded.

Bricks of high porosity—up to 30 per cent.—are at first rapidly attacked. When the raw meal and clinker have adhered to them there is a temporary cessation of attack, since the clinker protects them from abrasion. Dense bricks, on the other hand, are more susceptible to temperature changes, but resist abrasion better, especially at the beginning and towards the end of the run. The porosity should be between 7 and 30 per cent.

Additional information regarding the structure of kiln lining blocks is to be obtained by examining thin sections in transmitted and polarised light and polished sections in reflected light. The density of the bricks used in any kiln should be the same throughout. If some are more porous than others they will be attacked to a different degree, so much so that individual bricks may drop out into the kiln and cause burning of the iron shell. In the case of blocks pressed twice on the same side, on burning the brick shrinks more on the stamped side than on the side which was bedded, and the lined kiln has a toothed appearance. The projecting portions are rapidly worn away, which allows the calcareous slag to penetrate the brick, especially in the case of porous bricks. In such cases the entire lining is best covered with thin cement paste before putting the kiln in commission.

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Formulæ for the Control of Air Separation.

By A. B. HELBIG.

IT is generally agreed that grinding in closed circuit saves power and increases the output of a cement mill, and consequently air separation has become a matter of considerable interest. The addition of a separator to a grinding mill has not always in the past given the results expected, two of the principal reasons being (1) the mill construction does not allow the necessarily increased stream of material to be carried through the mill, and the lining and the charge of grinding bodies are not changed to suit the new conditions; (2) the lack of efficiency of the separator chosen. It is unfortunately true that the efficiency of an air separator decreases very rapidly with the increasing fineness of the product. For example, the output of an air separator 9ft. 4in. in diameter decreases from 16,000 kg. of cement with 10 per cent. residue on the German standard screen DIN 70 (with 4,900 meshes to the sq. cm.) to 2,500 to 2,800 kg. of cement, containing 55.8 per cent. of flour from 0 to 10 μ, 43.4 per cent. of flour from 10 to 20 μ and only 0.8 per cent. of flour over 20 μ. This disadvantage led to the invention of a new separator, which will shortly be on the market.

There are two methods of air separation. In the first process the material to be separated is mechanically elevated and thrown in a circulating airstream. The second process carries the feed out of the mill by an airstream of high velocity which takes much power. In order to get the necessary numerical values for the control of the air separator it is necessary to sample very carefully the feed Q, which is split by the separation into the coarse product C and the fine product F. True average samples of these three materials are screened thoroughly on the standard screen used in the test. According to these screening tests the feed Q contains r per cent. residue and g per cent. passes through the screen. The coarse product C has c per cent. residue on the screen, and, of the fine product F, f per cent. passes through the screen: $r+g=100$.

The abrasion during the process of air separation creates p per cent. more fine material because (1) some of the particles are crushed, (2) the fines adhering to the coarse particles are partially rubbed off, and (3) the agglomerates of fines are smashed.

We have then in the feed of the separator, instead of $\frac{Q\,r}{100}$ coarse material, $\frac{Q\,(r-p)}{100}$. And instead of $\frac{Q\,g}{100}$ fine material, $\frac{Q\,(g+p)}{100}$. These two parts of the feed are distributed in the two products C and F of the separation. The residue on the test screen is $\frac{C\,c+F\,(100-f)}{100}$. The fines going through are $\frac{C\,(100-c)+F\,f}{100}$.

From this consideration we get the two equations.

Residue: $Q \times (r-p) = C \times c + F \times (100-f)$ .. .. (1)

Fines: $Q \times (g+p) = C \times (100-c) + F \times f$ .. .. (2)

If equation (1) is subtracted from equation (2) the result is

$$Q \times 2p + Q \times (g-r) = F \times (2f-100) - C \times (2c-100)$$

$$g = 100 - r$$

$$p = r - 50 + \frac{F \times (f-50)}{Q} - \frac{C \times (c-50)}{Q} \quad .. \quad (3)$$

If the separator is combined with a mill, the abrasion assists the grinding. But the division of a finished product in its different grain sizes should, as much as possible, avoid abrasion, especially if the fine and finest flour is not desired. It is necessary for the determination of p to weigh the two products C and F, but this is not always easy. It will be proved later, however, that without the determination of p the numerical values calculated are false. Therefore the first step in the control of an air separating plant is to obtain by experiment an average value of p. With the value of p determined, we can calculate C and F. To this end, equation (1) has to be multiplied by f, and equation (2) by $(100 - f)$, and we have to subtract equation (2) from equation (1).

$$Q \times f \times (r + g - p + p) - Q \times (g + p) = C \times (cf + 100 \times f + 100 \times g - 100 \times 100 - c \times f)$$

$$100 \times Q \times (f - g - p) = 100 \times C \times (c + f - 100)$$

$$C = \frac{Q \times (f - p - g)}{c + f - 100} \quad .. \quad .. \quad .. \quad (4)$$

With a similar manner we get

$$F = \frac{Q \times (c + p - r)}{c + f - 100} \quad .. \quad .. \quad .. \quad (5)$$

The efficiency of the process of separation cannot be exactly determined, because it depends on the screen used. The results of two experiments can, however, be compared, if the same standard test screen has been employed.

Every process has two different efficiencies, namely (1) the efficiency of separation of the coarse material, and (2) the efficiency of separation of the fine material. The first efficiency is the quotient of the amount of coarse material in the coarse product of the separation by the coarse material in the feed:

$$n_c = \frac{C \times c}{Q \times (r - p)} \quad .. \quad .. \quad .. \quad .. \quad (6)$$

The second efficiency is the quotient of the flour in the fine product of the separation by the flour in the feed:

$$n_f = \frac{F \times f}{Q \times (g + p)} \quad .. \quad .. \quad .. \quad .. \quad (7)$$

The amount of material circulating in the air separator is found by the following consideration: the feed M going to the mill must be equal to the fine product (F) leaving the mill, $M = F$. The feed (Q) to the separator contains the fresh feed M and the circulating grits ($X \times M$). According to the screen analysis the feed Q has $(g + p)$ per cent. of flour. This amount of flour $M \times (X + 1) \times \frac{(g + p)}{100}$ is divided in the flour of the fine product $= \frac{M \times f}{100}$, and in the flour in the grits $\frac{M \times X \times (100 - c)}{100}$. The equation of the flour, if we multiply by 100 and divide by M, then reads

$$(X + 1) \times (g + p) = f + X \times (100 - c)$$

$$X = \frac{f - g - p}{g + c + p - 100}$$

The control of the separating installations will, in the opinion of the writer, in many cases cause surprises due to the imperfection of the present construction and the difficulties of the adjustment of the separator. Accurate adjustment can only be made by experts with a very thorough training and long experience; failure to recognise this fact has handicapped materially the use of the air separator. The new machine referred to can be adjusted without special knowledge of the plant.

Summary of Formulæ.

The separator feed Q contains r per cent. residue on, and g per cent. flour passing through, the screen.

The coarse product C of the separator leaves c per cent. residue on the screen.

The fine product F has f per cent. flour passing through the screen.

The flour in the feed is increased by p per cent. through abrasion.

The circulation in the plant is X times greater than the output F.

The abrasion $$p = r - 50 + \frac{F \times (f - 50)}{Q} - \frac{C \times (c - 50)}{Q}.$$

Coarse product $$C = \frac{Q \times (f - p - g)}{c + f - 100}.$$

Fine product $$F = \frac{Q \times (c + p - r)}{c + f - 100}.$$

Efficiency of the coarse separation $$n_c = \frac{C \times c}{Q \times (r - p)}.$$

Fine separation $$n_f = \frac{F \times f}{Q \times (g + p)}.$$

Circulation $$X = \frac{f - g - p}{c + g + p - 100}.$$

These formulæ allow an easy control of the process of separating in the shortest time.

Assuming that $Q = 100$ weight units, $r = 80$ per cent., $g = 20$ per cent., $p = 3$ per cent, $c = 95$ per cent., $f = 90$ per cent.

$$C = \frac{100 \times (90 - 3 - 20)}{95 + 90 - 100} = \frac{6,700}{85} = 78.82.$$

$$F = \frac{100 \times (95 + 3 - 80)}{95 + 90 - 100} = \frac{1,800}{85} = 21.18.$$

$$n_c = \frac{78 \times 82 \times 95}{100 \times (80 - 3)} = 0.9594, \text{ or } 95.94 \text{ per cent.}$$

$$n_f = \frac{21 \times 18 \times 90}{100 \times (80 - 3)} = 0.8288, \text{ or } 82.88 \text{ per cent.}$$

$$p = 80 - 50 + \frac{21.18 \times (90 - 50)}{100} - \frac{78.82 \times (95 - 50)}{100} = 3.003 \text{ per cent.}$$

$$X = \frac{90 - 3 - 20}{20 + 95 + 3 - 100} = \frac{67}{18} = 3.72.$$

If p is neglected and $p = 0$ is assumed, we get very different results:

$$C = \frac{100 \times (90 - 20)}{95 + 90 - 100} = \frac{7,000}{85} = 82.35.$$

$$F = \frac{100 \times (95 - 80)}{95 + 90 - 100} = \frac{1,500}{85} = 17.85.$$

The apparent efficiencies are

$$n_c = \frac{82.35 \times 95}{100 \times 80} = 0.9779, \text{ or } 97.79 \text{ per cent.}$$

$$n_f = \frac{17.65 \times 90}{100 \times 20} = 0.7942, \text{ or } 79.42 \text{ per cent.}$$

$$X = \frac{90 = 20}{95 + 20 - 100} = \frac{70}{15} = 4.67.$$

INTERNATIONAL DICTIONARY OF CEMENT.

Arranged by Dr. C. R. Platzman, with collaborators in England, France, and Spain.

English.	French.	German.	Spanish.
excavating machine	excavateur, grue	Löffelbagger	máquina excavadora
excavator	excavateur	Bagger	excavadora
excess	excès	Ueberschuss	exceso
exhaust, to	faire le vide	entleeren, ausschöpfm	agotar, extraer
exit gas	gaz brulé	Abgas	gas de escape
expand, to	gonfler	treiben	hinchar
expansion	expansion	Treiben, das	expansión
explosive	explosif	Sprengstoff	explosivo
extraction	extraction	Absacken, das Abziehen, das	extracción
	F		
factory	usine	Fabrik	fábrica
fan	ventilateur	Ventilator	ventilador
fast pulley	poulie fixe	Festscheibe	polea fija
fatty acid	acide gras	Fettsäure	ácido graso
feed	alimentation	Zufuhr	alimentación
feeding screw	vis alimentaire	Zufuhrschnecke	tornillo alimentador
filter cloth	tissu filtrant	Filtertuch	paño filtrante
final set	prise final	Abbindeende	fin del fraguado
fineness	finesse de mouture	Mahlfeinheit	finura
fineness modulus	module de finesse	Mahlfeinheitsmodul	módulo de finura
firebrick	brique réfractaire	feuerfester Stein	ladrillo refractario
flame tube boiler	chaudière à tubes de fumée	Flammrohrkessel	caldera de tubos de humo
flexible coupling	joint élastique	Gelenkkupplung	acoplamiento elástico
flint	cailloux, silex	Flintstein	guijarro, silex
flow table	doseur à plateau	Fliesstisch	tablero de fluidez
flue	carneau	Fuchs (Ofin)	conducto
flue dust	poussière des fumées	Abgasstaub	polvo de la chiminea
flux	fondant	Flussmittel	fundente
fly-wheel	volant	Schwungrad	volante
foundry	fonderie	Giesserei	fundición
fracture	cassure	Bruch	fractura
frame	cadre	Rahmen	marco o bastidor
friction	frottement	Reibung	rozamiento
fuel	combustible	Brennstoff	combustible
fume	fumée	Rauch	humo
fuse	coupe circuit	Sicherung (elektr.)	válvula fusible
fusion	fusion	Schmelzen, das	fusión
	G		
gantry	échafaudage, ossature	Gangbrücke	conducto de protección
gas coal	houille demi-grasse	Gaskohle	carbón semi-graso
gauge, to	gâcher	anmachen	amasar
gel	gel	Gel	gel
generating station	station d'énergie, station génératrice	Kraftstation	central de energia
grab	benne	Greifer	cuchara
grab-crane	grue à benne preneuse	Greiferkran	grúa de cuchara prensora
graduated measuring tube	éprouvette graduée	graduiertes Messrohr	probeta graduada
grain size	grosseur de grain	Korngrösse	grano mezclado
grate	grille	Rost	parrilla
gravel	agrégat	Kies	gravilla
gravimetric analysis	analyse gravimétrique	Gewichtsanalyse	análisis gravimetrico
gravity	pesanteur	Schwerkraft, Gewicht	peso

(*Continued on page* 128.)

ENGLISH.	FRENCH.	GERMAN.	SPANISH.
gravity of volume	densité apparente	Raumgewicht	densidad aparente
grease	graisse	Fett	grasa
grind, to	broyer, moudre	mahlen	moler
grinding ball	boulet pour broyeur	Mahlkugel	bola molturadora
grinding medium	corps broyeur	Mahlkörper	elemento molturador
grit	farine, sablette	Gries	material triturado
groove	gorge	Rille, Verengung, Kehle	garganta, acanaladura
gudgeon	tourillon, goujon	Zapfen, Bolzen	chaveta
guide pulley	poulie à gorge	Führscheibe	polea guía
gun metal	bronze	Geschützmetall	bronce
gypsum	gypse	Gips	yeso
gyratory crusher	concasseur giratoire	Kreisel-, Kegelbrecher	machacadora giratoria
	H		
hammer crusher	broyeur à marteaux	Hammerbrecher	trituradora de martillos
hand filling	mise en sacs à la main	Abfüllen, von Hand	envasado a mano
hand lever	levier	Handhebel	pabanca de mano
hardening	durcissement	Erhärtung	endurecimiento
harrow	herse, râble	Egge	castrillo
heat	chaleur	Wärme	calor
heat balance	bilan thermique	Wärmebilanz	balance térmico
heat exchange	échange de chaleur	Wärmeaustausch	intercambio de calor
heat of solution	chaleur de dissolution	Lösungswärme	calor de disolución
heat recovery	récupération de la chaleur	Wärmerückgewinnung	recuperación del calor
heat transmission	transmission de la chaleur	Wärmeübertragung	transmisión del calor
hoisting machinery	appareil de levage	Aufzug	elevador
hoist tippler	déchargeur-élévateur	Kippheber	elevador volcador
hole	ouverture	Loch, Oeffnung	agujero
hollow shaft	arbre creux	Hohlwelle	eje hueco
hopper	trémie	Trichterbehälter	tolva
horse power	cheval-vapeur	Pferdekraft	caballos pe vapor
hose pipe	tuyau souple	Gelenkrohr, -schlauch	manguera
humidity	humidité	Feuchtigkeit	humedad
hydrate of lime	hydrate de chaux	Kalkhydrat	hidrato de cal
hydraulic lime	chaux hydraulique	Wasserkalk	cal hidráulica
hydraulic press	presse hydraulique	hydraul. Presse	prensa hidráulica
hydrochloric acid	acide chlorhydrique	Salzsäure	ácido clorhidrico
hydrofluoric acid	acide fluorhydrique	Flussäure	ácido fluorhidrico
hydrogen	hydrogène	Wasserstoff	hidrógeno
hydrous oxide of aluminium	oxyde d'aluminium hydraté	Aluminiumhydroxyd	óxido de aluminio hidratado
	I		
impact testing machine	machine d'essai au choc	Schlagprobemaschine	máquina de ensayo al choque
impermeability	imperméabilité	Undurchlässigkeit	impermeabilidad
incipient fusion	commencement de fusion	Sinterung	fusión incipiente
increase, to	augmenter	steigern, vermehren	aumentar
induced draught	tirage mécanique	Saugzug	tiro forzado
initial set	prise initiale	Abbindebeginn	principio del fraguado
initial speed	vitesse initiale	Anfangsgeschwindigkeit	velocídad inicial
insoluble residue	résidu insoluble	unlöslicher Rückstand	residuo insoluble
insufficiently burnt	incuit	Schwachbrand	cocción insuficiente
insulator	isolateur	Isolator	aislador
iron	fer	Eisen	hierro
	J		
jackhammer air drill	perforatrice à percussion fonctionnant à l'air comprimé	Luftbohrhammer	barrena montada en martillos de aire comprimido

(*Continued on page* 129.)

ENGLISH.	FRENCH.	GERMAN.	SPANISH.
jarring machine	appareil à secousses ; machine à mouvement vibratoire	Rüttelmaschine	máquina asentadora
jaw crusher	concasseur à mâchoires	Backenbrecher	machacadora de mandíbulas
jet	bec	Düse	boquilla
joint	joint	Gelenk, Fuge	junta
journal	journal, revue, coussinet	Zeitschrift	revista
	K		
kiln	four	Ofen	horno
kiln hood	coiffe du four	Ofenkopf, Ofenhaube	caperuza del horno
kiln lining	garnissage du four	Ofenfutter	forro o revestemiento del horno
kiln shell	enveloppe du four	Ofenmantel	cubierta del horno
	L		
lathe	tour	Drehbank	torno
lens	loupe	Lupe, Linse	lente
level	niveau	Niveau	nivel
light railway	chemin de fer à voie étroite	Kleinbahn	ferrocarril de via estrecha
lime	chaux	Kalk	cal
lime modulus	module de la chaux	Kalkmodul	módulo cálcico
limestone	calcaire, pierre à chaux	Kalkstein	caliza
liquid	liquide	Flüssigkeit	líquido
load	charge	Belastung	carga
load limit	limite de charge	Belastungsgrenze	límite de carga
locomotive	locomotive	Lokomotive	locomotora
loose pulley	poulie folle	Losscheibe	polea loca
loss of weight	perte de poids	Gewichtsverlust	pérdida de peso
loss on ignition	perte au feu	Glühverlust	pérdida al fuego
lubricant	lubrifiant	Schmierfett	lubricante
lubricate, to	lubrifier	schmieren	engrasar
	M		
magnesite brick	brique de magnésie	Magnesitstein	ladrillo de magnesita
magnetic clutch	embrayage magnétique	Magnetkupplung	embrague magnético
magnification	grossissement	Vergrösserung	aumento
maintenance	entretien	Unterhaltung, Wartung	funcionamiento
malleable iron	fonte malléable	Tempergusseisen	hierro maleable
manilla	manille	Manilahanf	abacá
manufacturing process	procédé de fabrication	Fabrikationsprozess	proceso de fabricación
marl	marne	Mergel	marga
mercury switch	interrupteur à mercure	Quecksilberschalter	interruptor de mercurio
mesh	maille	Masche	malla
meter	mètre	Meter	metro
mild steel	acier doux	Schmiedestahl	acero dulce
mill	usine, moulin	Mühle	molino
mixing screw	vis mélangeuse	Mischschnecke	tornillo mezclador
mixing tank	bassin à mélangeurs	Mischtank	silo de mezcla
mixing water	eau de gâchage	Anmachewasser	agua de amasado
moisture	humidité	Feuchtigkeit	humedad
mortar mixing machine	malaxeur à mortier	Mörtelmischmaschine	mezcladora de mortero
mould, to	mouler	formen	moldear
mud	boue, vase	Lehm	barro
muffle furnace	fourneau à mouffle	Muffelofen	horno de mufla
	N		
nail	clou	Nagel	clavo
narrow-gauge railway	chemin de fer à voie étroite	Schmalspurbahn	ferrocarril de vía estrecha

(*Continued on page* 130.)

ENGLISH.	FRENCH.	GERMAN.	SPANISH.
navvy	grue, excavateur	Löffelbagger	pala, maquina excavadora
needle	aiguille	Nadel	aguja
nitric acid	acide nitrique	Salpetersäure	ácido nítrico
nitrogen	azote	Stickstoff	nitrógeno
normal consistency	consistance normale	Normalsteife	consistencia normal
nozzle	tuyère	Düse	boquilla
	O		
oil	huile	Oel	aceite
opening	orifice	Oeffnung	abertura
operating costs	dépenses d'exploitation	Betriebskosten	coste de funcionamiento
optical pyrometer	pyromètre optique	optisches Pyrometer	pirómetro óptico
ore	minerai	Erz	mineral
overload	surcharge	Ueberlastung	sobrecarga
oxygen	oxygène	Sauerstoff	oxígeno
	P		
packing machine	machine à empaqueter, ensacheuse	Packmaschine	máquina envasadora
packing machinery	machinerie d'empaquetage	Packmaschinerie	maquinaria de envasado
pad	bourrelet, coussinet	Griff	mango
pat of cement	galette de ciment	Zementkuchen	galleta de cemento
pedestal	chaise	Lager, Lagerrahmen	soporte o cojinete
percentage	proportion centésimale	Prozentgehalt	tanto por ciento
perforate, to	perforer	durchlochen	perforar
permeability	permeabilité	Durchlässigkeit	permeabilidad
photomicrograph	photomicrographie	Mikroaufnahme	microfotografia
pier	pilier	Pfeiler	pilar
pinion shaft	arbre à pignon	Ritzelwelle	eje del piñón
pinion spur wheel shaft	arbre avec pignon à denture droite	Zahnkranzritzelwelle	eje que acciona la corona dentada
pipeline	conduite	Rohrleitung	tuberia
piston	piston	Stempel Kolben	émbolo
pit	fosse	Grube	cantera
plain bearing	palier lisse	Gleitlager	cojinete ordinario
plaster of Paris	plâtre de Paris	Stuckgips	yeso de Paris
platform weighing machine	balance à plateforme	Plattenwaage	máquina pesadora de plataforma
plunger	piston plongeur	Tauchstab, Plunger	émbolo zambullidor
plunger pump	pompe à piston plongeur	Plungerpumpe	bomba de émbolo zambullidor
pneumatic conveying plant	manutention pneumatique	Pneumatische Förderanlage	instalación de transporte neumático
point of fusion	point de fusion	Schmelzpunkt	punto de fusión
potassium	potassium	Kalium	potasio
power	énergie	Kraft	energía
power consumption	consommation d'énergie	Kraftverbrauch	consumo de energia
power factor	facteur de puissance	Leistungsfaktor	factor de potencia
power plant	installation de force motrice	Kraftanlage	centrale de fuerza
power station	station génératrice ; station d'énergie	Kraftstation	centrale de energia ; centrale eléctrica
precipitate	précipité	Niederschlag	precipitado
pressure	pression	Druck	presión
pulverizer	pulvérisateur	Mahlvorrichtung	pulverizador
pumice	pierre ponce	Bimsstein	piedra pómez
pump	pompe	Pumpe	bomba
pump, to	pomper	pumpen	bombar
push-button control	commande par boutons-poussoirs	Druckknopfsteuerung	pulsador

(*To be continued.*)

The Hardening and Corrosion of Cement—IV.

By Dr. KARL E. DORSCH.

(Of the Technical High School, Karlsruhe, Baden.)

The Electrical Conductivity of Setting Cement.

Viscometric measurements have shown that the setting of cement is in all probability not uniformly continuous, but is a rhythmic process. It has been pointed out that the irregularities can be explained by the gel theory. The viscosity of setting cement depends on the chemical reactions taking place, so that these reactions must also proceed irregularly. During setting the chemical nature of the cement changes, in that calcium hydroxide and various calcium hydroaluminates and hydrosilicates are formed, some soluble in water and others only very slightly soluble. As these chemical reactions proceed the electrical conductivity of the setting cement changes, and these changes can be measured.

The electrical conductivity of setting cement has been measured by H. Gessner[13] and Yosomatsu Shimizu.[14] Gessner carried out two experiments, in the first of which a few grammes of cement were mixed with 50 c.c. of water and the conductivity of the solution was measured by means of the Ostwald immersion electrode. In these experiments the cement was mixed with 37.5 and 75 per cent. of water. They were thus not carried out on cement paste of technical proportions, but approximate to the conditions holding in microscopic preparations. In both cases the specific conductivity was measured from the beginning of the experiment until 4 hours 50 minutes had elapsed; the next measurements were made at the end of 18 hours, and the period between 5 and 18 hours was neglected. The experiments were continued for 223 days.

This investigation showed that the electrical conductivity of setting Portland cement rapidly increases during the first hour after mixing, and then rapidly and steadily diminishes. After 20 hours the conductivity curve becomes flatter and finally runs parallel to the time abscissa. The maximum conductivity was attained in about 40 minutes. The occurrence of the maximum is explained by Gessner by supposing that the liquid phase is at this stage saturated with $Ca(OH)_2$ and that the solid hydrate begins to be deposited. The rapid saturation of the water with $Ca(OH)_2$ is due to part of the water having already combined with the constituents of the clinker. The falling off in conductivity occurs when part of the water of the liquid phase is abstracted by the solid substances present. The experimental results are, however, insufficiently complete to allow satisfactory conclusions to be reached.

Gessner's results are contradicted by the work of Y. Shimizu on the setting and hardening of mixed cements containing basic blastfurnace slag. It is well known that blastfurnace slag which has been quenched in air or water possesses feeble hydraulic properties. Its reaction with water is, however, so extremely

[13] H. Gessner, *Kolloid Zeits.*, Vol. 36, 1928; Vol. 37, 1929.
[14] Y. Shimizu, World Power Conference, Tokyo, 1929, Paper No. 162.

slow that it cannot in itself be used as a cement, but must be mixed with other cements, generally Portland. The reaction between the cement and the mixing water increases the activity of the slag, and it is reasonable to suppose that this phenomenon will find expression in the electrical conductivity curve of the mixed cement. Such a curve was obtained in 1927 at the Yawata Steelworks, Japan, for a blastfurnace cement maintained at 30 deg. C. during setting (Fig. 27). The curve showed a slight increase in conductivity during the first hour after mixing. During the second hour the conductivity fell somewhat, and at the end of two hours it had attained an almost constant value. After five hours the curve showed a new and more pronounced fall which flattened out considerably after a further 1½ hours. At the end of the seventh hour the curve again fell steeply, and again flattened out after eight hours. There are thus two pronounced falls, one after five hours and the other after seven hours. The fall

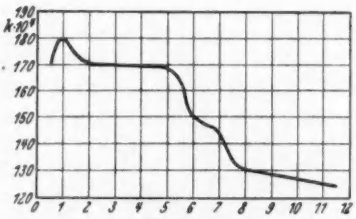

Fig. 27.—Conductivity curve for Blastfurnace Cement obtained at the Yawata Steelworks.

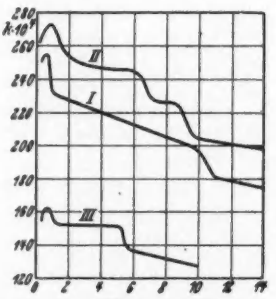

Fig. 28.—Shimizu's measurements: I.—Blastfurnace Slag; II.—75 parts Slag + 25 parts Portland Cement; III.—30 parts Slag + 70 parts Portland Cement.

after 5 hours is attributed by Shimizu to the hydration of the cement, and after 7 hours to the hydration of calcium silicates in the blastfurnace slag, and he has attempted to prove this as follows: Before mixing, the cement, water, and the entire apparatus were brought to the same temperature. A cement paste of normal consistency was mixed and placed in a glass vessel, two platinum electrodes being immersed vertically in the cement. The glass vessel was placed in a thermostat at 30 deg. C. and the electrodes were connected to a Kohlrausch bridge, measurements of conductivity being made every 5 or 10 minutes.

Measurements were first made on a blastfurnace slag-water mix, without cement (Fig. 28, curve I). A break in the curve occurred after 10 hours, and should correspond to the fall at 7 hours in Fig. 27. Mixtures of 90, 80, 70, etc., per cent. slag with 10, 20, 30, etc., per cent. Portland cement were then investigated, and the two falls in the curve were evident (Fig. 28, curve II) at 6 hours and 9 hours. As the proportion of Portland cement increased the time interval between the two breaks in the curve became smaller, until finally,

at a certain ratio of Portland cement to slag, they merged into each other and became one (Fig. 28, curve III): Shimizu found that the composition of the mixture when the two breaks merged was exactly that of iron-Portland cement. It has thus been shown that the setting and hardening of blastfurnace slag are accelerated by additions of Portland cement, and that with a certain suitable mixture the two reactions occur together.

Shimizu carried out further experiments with aluminous cement and blastfurnace slag mixed in all proportions. Pure aluminous cement gave a break in the electrical conductivity curve after four hours. With the mixtures it was found that the setting and hardening of slag are accelerated by additions of aluminous cement to a greater extent than by Portland cement. The two breaks in the conductivity curve run together with a mixture 40 parts of slag to 60 parts of aluminous cement. On testing the crushing strengths of these mixtures of slag and Portland or aluminous cement Shimizu found a maximum, which occurred with the mixtures for which the two breaks in the conductivity curve were merged together. Thus the most advantageous proportions for a slag-Portland cement mixture are 3 : 7, and for slag-aluminous cement 4 : 6.

These investigations give completely different results from those of Gessner. This is probably mainly due to the facts that Gessner did not make measurements between the fourth and eighteenth hours and that he only carried out two experiments. In connection with Shimizu's work it is very desirable definitely to establish which chemical reactions in the setting of cement and slag correspond to the observed breaks in the conductivity curve. This is the more important because the term " setting and hardening " cannot be employed in the same sense for slag as for cement. It is also desirable to investigate the relation between the crushing strength maximum and the merging of the two breaks in the curve. Is the connection between these two phenomena accidental or fundamental? It has been found—and this must be taken into consideration in assessing Shimizu's results—that the addition of 30 per cent. of non-hydraulic slag to many Portland cements causes no reduction in strength, and that with still greater additions of such slag the strength decreases in exactly the same way as that of the mixed cements investigated by Shimizu. The fact that additions of 30 or 40 per cent. slag to certain Portland cements give no reduction in strength may be in part explained by the gradation of grain size resulting from the admixture of slag dust with the standard sand used in testing, giving a denser and stronger mortar when slag is used than with standard sand alone.

The fact that the strength of many cements is not reduced by additions of slag is important. Different cements react entirely differently to added materials, depending on their chemical composition, which in its turn depends on the raw materials and the manner of burning. The author has observed a case in which the strength of a cement containing 30 per cent. of added fine coal ash was as high as that of the pure cement, while with another cement 10 per cent. of the same ash caused a reduction in strength. Theoretically it is to be expected that every slag will react differently with every cement, so that differences in

the course of setting and in the electrical conductivity are to be anticipated. These factors have not been sufficiently taken into consideration by Shimizu.

Theoretically we should expect the opposite of Shimizu's finding that the specific conductivity of the pure slag ($k \times 10^4 = 250$) is greater than that of a mixture of 70 parts Portland cement and 30 parts slag ($k \times 10^4 = 160$), as shown in Fig. 28. We should rather expect to find that the conductivity of the slag (gauged with water), owing to its much lower lime solubility, was lower than that of a mixture consisting mainly of Portland cement. Shimizu's work may be further criticised in that the whole of the measurements were made at the temperature of 30 deg. C., which does not correspond to practical conditions.

The author therefore decided to undertake a series of systematic measurements with the object of clearing up the contradiction between the previous results. The work was first confined to the study of the variation of the specific

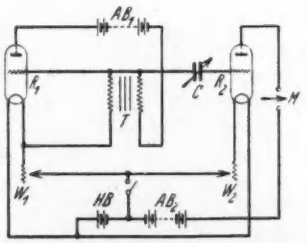

Fig. 29.—Valve Oscillator for measurement of electrical conductivity.

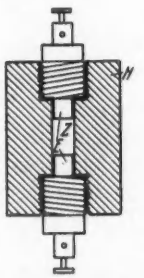

Fig. 30.—Electrical conductivity cell.

electrical conductivity of a number of cements with time, and of the effects of different additions of water and of temperature on the conductivity curve.

Method of Measurement.

To obtain satisfactory results in work of this nature it is essential that it should be carried out at constant temperature, and a gas-heated thermostat was accordingly used. Series of measurements were carried out at 20, 30 and 40 deg. C., and the cement and water were heated to the required temperature before each experiment. It was first necessary to work out a method of making the electrical measurements suited to the peculiarities of the materials under investigation. The equipment used by Kohlrausch was first tried. This consists of an induction coil, a measuring wire stretched on a scale, along which moves a sliding contact, a telephone, a comparison resistance, and a vessel to contain the electrolyte. In the preliminary experiments two immersion electrodes were employed, immersed vertically in the cement paste. Owing to the high viscosity of the paste the distance apart of the electrodes was appreciably altered during immersion, causing errors such that consecutive control tests gave different results. The distance between the electrodes was further affected when the hardened

cement began to swell or shrink. An additional difficulty was the relatively wide range over which the minimum noise in the telephone persisted, due to the colloidal nature of the cement paste; this could be only very slightly corrected even by inserting condensers in parallel. This last and other difficulties were eliminated by adopting a modified form of the Ostwald-Luther valve oscillator,[15] shown diagrammatically in Fig. 29. R_1 and R_2 are two suitable radio valves (R_1 is a Telefunken RE064 and R_2 a Telefunken RE114), and W_1 and W_2 two resistances regulating the filament-heating current obtained from battery HB. The high-tension battery AB_1 supplies the anode of valve R_1, and battery AB_2 the anode of valve R_2. T is a 1:4 intervalve transformer (primary 5,000, secondary 20,000 turns). C is a constant or variable condenser of 300 cm. capacitance. The current is conveyed to the measuring bridge via M. This circuit is necessary because the original Ostwald-Luther oscillator, which employs only one valve, gives sound of insufficient volume. The valve oscillator described gives a note of any desired frequency, starts up instantaneously, and remains absolutely constant even when run for 24 hours. When the bridge was calibrated with known metal resistances the minimum sound in the telephone could be accurately observed within 0.1 mm. on the scale of the measuring wire. A good 10,000-ohm rheostat was used as balancing resistance. A 100-ohm telephone was employed, and as this was not quite symmetrical a 4,000-ohm resistance was connected in parallel. The symmetry was then accurately tested and the mean value taken.[16]

After a number of experiments the conductivity cell shown in Fig. 30 was designed and found satisfactory. H is an ebonite cylinder, bored cylindrically. Two brass electrodes E with platinum caps are screwed in; the area of the ends of these electrodes is 2 sq. cm. and they are 2 cm. apart. The space between them Z is filled with the cement paste to be studied. In filling, the bottom electrode is screwed in, a sufficient quantity of cement paste is inserted on a spatula, and the upper electrode is screwed in. Both electrodes are screwed down so that they are firmly bedded, thus maintaining a constant distance between them in successive experiments, which does not vary during the course of the measurements.

In carrying out an experiment, cement, water, and thermostat were first brought to the required temperature. One hundred grammes of cement were then mixed with the required amount of water and the mixture was vigorously agitated for three minutes. A small quantity of the paste was transferred to the conductivity cell on a spatula, filling to a given mark, and the second electrode was screwed in. The cell was then placed in the thermostat and connected to the measuring bridge. The circuit was finally closed by means of a switch, and the minimum in the telephone was obtained. The specific conductivity was thus determined; this is given by $k = CbR/a$, where C is the resistance of the cell, R that of the rheostat, and a and b are the lengths of the measuring wire

[15] Ostwald-Luther, *Physico-chemical Measurements*, p. 505 (1925).
[16] Hall and Adams, *J. Amer. Chem. Soc.*, Vol. 41, p. 1515, 1929; Hausrath and Krüger, *Helios*, Vol. 15, No. 49, 1909.

divided by the sliding contact. The constant C was obtained by filling the cell with a liquid of known specific conductivity. No difficulties were experienced in making the measurements and the results were satisfactorily reproducible.

Results.

The conductivity of many different cements was investigated. The percentage analyses of certain of these are given in Table IV, and the conductivity results are set out in the following tables and diagrams.

TABLE IV.

	High-strength Portland.	Ordinary Portland.	Blastfurnace Cement.	Aluminous Cement.
Loss on ignition ..	0.95	0.70	2.20	0.56
Insoluble residue..	1.33	0.93	1.61	0.60
SiO_2	17.72	19.94	27.36	6.10
CaO	65.38	63.44	49.72	34.04
Al_2O_3	5.76	6.49	—	48.56
Fe_2O_3	3.96	3.53	15.80	10.44
MgO	1.96	2.33	0.80	0.18
SO_3	2.60	1.77	2.52	0.27

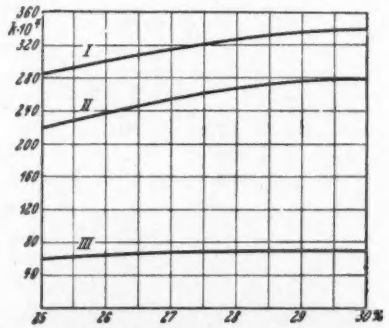

Fig. 31.—Relation between electrical conductivity and quantity of mixing water. I.—High-strength Portland; II.—Blastfurnace; III.—Aluminous Cement.

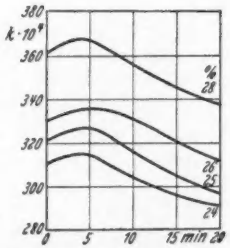

Fig. 32.—Portland Cement.

The effect of varying amounts of mixing water on the specific conductivity of the cements was first investigated. It was found in all cases that the conductivity increased with the amount of mixing water. This would appear to follow from the fact that with higher water content there is a greater quantity of electrolyte present in the same space.

The conductivity curves for the high-strength Portland, blastfurnace and aluminous cements are given in Fig. 31 (curves I, II and III respectively) and in Table V.

Table V.

Water Content. Per cent.	High-strength Portland. $k \times 10^4$	Blastfurnace. $k \times 10^4$	Aluminous. $k \times 10^4$
25	285	220	60
26	298	235	63
27	316	250	67
28	328	266	68
29	333	275	69
30	340	280	70

The conductivity curves of Fig. 31 not only show that the conductivity in all cases increases with the water content, but also that there are considerable differences between the conductivities of different types of cement. The aluminous cement has a much lower conductivity than the blastfurnace cement, and the latter than the Portland. It is logical to connect this difference with the lime content of the cements. The analyses (Table IV) show that the lime content of the Portland cement is about 30 per cent. higher than that of the blastfurnace cement, the lime content of which is in its turn about 45 per cent. higher than that of the aluminous cement. We shall later find the same order—Portland, blastfurnace, aluminous—when the effect of aggressive salt solutions is investigated. If, for example, hardened cement is placed in a sulphate solution, the water-soluble calcium hydro-salts—and particularly calcium hydroxide—formed during setting and hardening react with the sulphate to form soluble $CaSO_4$. This $CaSO_4$ formation gives rise to the well-known deterioration of cement and concrete. The extent of this depends on the lime content of the cement (although it is not proportional to lime content), and we find that the order of resistance of different cements to the attack of sulphate solutions is the same as this order of decreasing electrical conductivity of the setting cements. Conversely it may be deduced in general that the lower the electrical conductivity of a cement, the higher will be its resistance to attack by salt solutions. Further, since the conductivity increases with the quantity of mixing water, resistance to chemical attack is increased by reducing the proportion of water—a result of practical importance. From a consideration of Fig. 31 it is to be expected that a Portland cement mixed with a small proportion of water (25 per cent.) will offer approximately the same resistance to chemical attack as a blastfurnace cement mixed with a large amount of water (30 per cent.). To what extent these deductions from electrical conductivity measurements agree with practice will be indicated by the investigations described later.

Figs. 32 to 34 show how the conductivity of the different cements varies during the period immediately after mixing. The Portland cement (Fig. 32) is characterised by a small rise in conductivity in the first few minutes, followed by a rapid fall. The blastfurnace cement (Fig. 33) shows an immediate fall in conductivity. Frequently, however, blastfurnace cements give a rise in conductivity

in the first few minutes after mixing, similar to Portland cement. The conductivity of aluminous cement first rises somewhat, and then falls after approximately 15 minutes. The initial increase in conductivity is connected with the solution of calcium hydrate or of calcium hydro-compounds. With the blastfurnace cement of Fig. 33 this solution has already taken place during the mixing.

It is important to investigate the effect of temperature on the electrical conductivity of cement. With this object tests were made at 20 and 30 deg. C. on high-strength Portland cement using different additions of water (Figs. 35 and 36). At the higher temperature a considerable increase in the specific conductivity (almost 18 per cent.) had occurred in 20 minutes. This is explained by the increased solubility of calcium hydrate at the higher temperature. Returning to the relation between electrical conductivity and the resistance of cement to chemical attack, it is to be anticipated that cements which set at higher temperatures or at temperatures artificially raised (*cf.* the use of additions to protect against frost in winter) will be less resistant than cements which set at

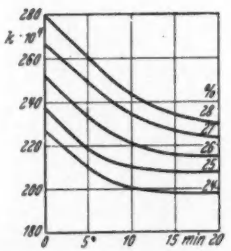

Fig. 33.—Blastfurnace Cement.

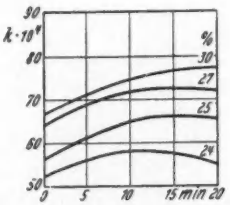

Fig. 34.—Aluminous Cement.

lower temperatures. Further experiments must, however, be carried out before such broad conclusions may be drawn. Quite apart from this, United States investigators have recently observed in practice that aluminous cement, which becomes very hot during setting and hardening, shows much lower resistance to the action of aggressive waters. Once the relation between electrical conductivity and resistance to chemical attack has been experimentally established, the exact measurement of conductivity will provide a definite criterion for this property. Work with this object is at present in progress.

The conductivity curves of the various cements were investigated over a period of two days at different temperatures and with different additions of mixing water, and the results are presented in Figs. 37 to 40. Every experiment was repeated several times and satisfactorily reproduced. In the case of Portland cement (Fig. 37) a small initial increase in the conductivity can be seen, the maximum being reached after some 20 minutes. The curve then rapidly falls, and flattens out after about an hour. The conductivity then remains approximately constant for about two hours, after which a rapid fall again begins. At

the end of the tenth hour the curve again flattens out and henceforth falls only slowly. After two days the conductivity has become almost constant.

Curves I to III of Fig. 37 present small differences which will now be considered. Curve I was obtained at 16 deg. C. and curve II at 20 deg. using 29 per cent. mixing water in each case. We again find that higher temperatures correspond to higher conductivities. Since the speed of setting is greater at the higher temperature, curve II intersects curve I after only five hours, and reaches lower conductivity values much more rapidly. Curve III was obtained with 28 per cent. mixing water at 20 deg. C. The conductivity values of this curve are lower than those of curve II, corresponding to the lower water content. These two curves run approximately parallel, as the velocities of reaction are almost equal at the same temperature. Curve IV represents 26 per cent. mixing water and 20 deg. C., and as expected lies below curve III. The water content in this experiment is nearest that used in the viscometric measurements (*see* Figs. 23

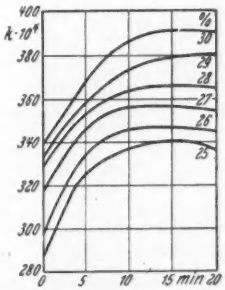

Fig. 35.—High-strength Portland Cement at 20 deg. C.

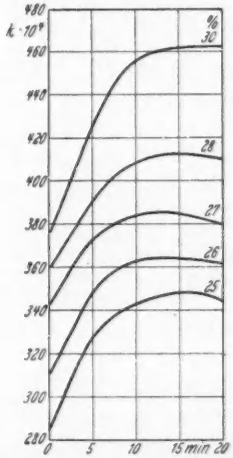

Fig. 36.—High-strength Portland Cement at 30 deg. C.

and 24, " Cement and Cement Manufacture," December, 1932), so that a comparison is justified: the curves obtained by the two entirely different methods show a remarkable similarity. Curve V was obtained at 40 deg. C. using 28 per cent. mixing water, and the effect of temperature on the velocity of reaction is again clearly shown. It intersects all the other curves and the conductivity becomes constant after so short a time as three hours.

The conductivity curves of the blastfurnace cement (Fig. 38) are very similar to those of Portland. The chief difference is that the conductivity values are somewhat lower than for Portland owing to the lower lime content. Curve I was obtained at 16 deg. C. using 29 per cent. water. The conductivity rises

somewhat in the first 20 minutes, reaches a maximum, and then falls during the next 20 minutes. At about the end of the first hour the curve flattens and the conductivity remains approximately constant for four hours. A rapid fall then sets in anew, with a gradual flattening after a total of 10 hours. In two days the conductivity has attained an almost constant value. The effect of varying the quantity of mixing water is clearly shown by curve II, which was obtained at the same temperature as curve I, but with 28 per cent. water. The conductivity is lower than with 29 per cent. water and constancy is reached somewhat earlier. The effect of temperature is demonstrated by curve III (20 deg. C. and 28 per cent. water). The higher velocity of reaction causes intersection of the curves. This effect is much more pronounced with curve IV, obtained at 40 deg. C., which intersects all the other curves.

The behaviour of aluminous cement (Fig. 39) is again very similar, and need not be considered in detail. The conductivity values are in this case much lower

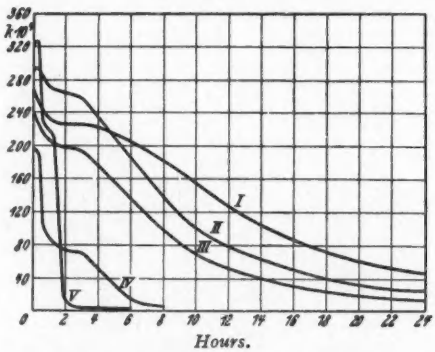

Fig. 37.—Conductivity of Portland Cement.

than with Portland and blastfurnace cements, and the curves clearly show that the reaction is more quickly completed. The upper curve of Fig. 39 represents 26 per cent. water and 16 deg. C., and the lower curve 25 per cent. water and 16 deg. C. The similarity with the viscosity curves of the setting cement (Fig. 26) is again obvious.

Blastfurnace cement consists of 70 parts slag and 30 parts Portland cement, and it will be interesting to investigate the conductivity curves of the basic slag. The slag used in these experiments had the following percentage composition : Insoluble residue, 3.32 ; loss on ignition, 0.28 ; SiO_2, 29.48 ; Al_2O_3, 18.22 ; Fe_2O_3 + FeO, 3.34 ; CaO, 42.24 ; MgO, 1.50 ; SO_3, 0.70 ; and sulphide sulphur, 0.85. Curves were obtained using 29 per cent. mixing water at 20 and 30 deg. C. (Fig. 40). It will be observed that the conductivity rose in the first hour and then fell in a parabola-like curve without interruption ; this coincides with Shimizu's results.

Let us now consider the explanation of these results. Obviously on mixing the cement and for some time afterwards, CaO (in the case of Portland and blast-

furnace cements) or $CaO.Al_2O_3$ (with aluminous cement) passes into solution causing an increase in the conductivity. At the maximum point of the curve saturation is reached and $Ca(OH)_2$ begins to crystallise out, or monocalcium aluminate reacts with $Ca(OH)_2$ forming crystalline polycalcium aluminates, particularly tricalcium aluminate. At the same time rapid hydration proceeds with gel formation and abstraction of water from the gel, so that the solid $Ca(OH)_2$ formed is enclosed in gelatinous envelopes. The conductivity therefore falls, the more rapidly when the gel formation is more vigorous. Finally, after about an hour—as is conclusively shown by the viscometric measurements—gel formation has progressed so far that it slows down the reaction. The cement particles are surrounded by thick envelopes of gel and the further action of water is prevented for a considerable period. The conductivity accordingly falls no further, or at best only very slowly. This condition persists for some two to

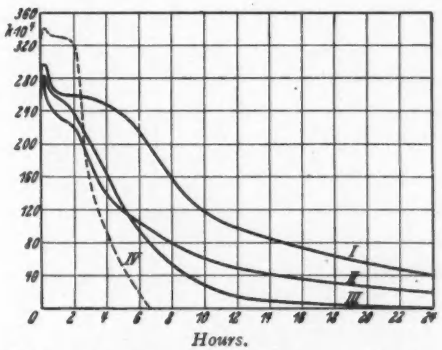

Fig. 38.—Conductivity of Blastfurnace Cement.

three hours, depending on the nature of the cement. It appears probable that a splitting open of the gel envelopes next ensues, allowing the water renewed access to the grains of cement, and a further fall of conductivity begins. Gel formation again takes place, and the more vigorous the action of the water the more is the production of gel accelerated and the steeper is the fall in the conductivity curve. This is clearly demonstrated by the effect of temperature on the curves.

Finally, the formation of gel progresses so far that the velocity of reaction is again reduced—after about 10 hours with Portland, 12 hours with blastfurnace and six hours with aluminous cement. This corresponds to final set according to the definition of Vicat. The conductivity henceforth falls very slowly, and at the end of two days becomes practically constant.

With slag the reaction proceeds differently. In itself basic blastfurnace slag is not hydraulic, i.e., it develops no strength when mixed with water. It may thus be accepted that in a mixture of slag and water colloidal reactions and gel formation proceed much more slowly and to a much less extent than with cement.

The electrical conductivity curve of such a mixture presents none of the irregularities of the cement curves, which may be attributed mainly to the rapid progress of gel formation. The rise in the conductivity of slag during the first hour is explained by the solution of lime, the attainment of the maximum by saturation of the lime solution, and the parabola-like falling curve by the abstraction of water from the solution during salt formation and hydration of the calcium silicates and aluminates. Owing to the slowness of the reaction all these changes proceed very gradually, so that the limited gel formation does not prevent the continuous action of the water upon the grains of slag.

Further research is necessary before it can be decided whether, when mixed with Portland cement, the slag becomes endowed with hydraulic properties and participates in gel formation. The electrical conductivity curves of blastfurnace cement appear to indicate that the velocity of reaction of slag is greatly accelerated by the addition of Portland cement, and that the slag is "opened up." The

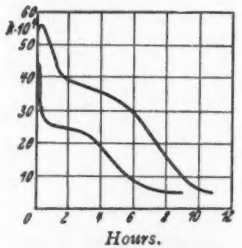

Fig. 39.—Conductivity of Aluminous Cement.

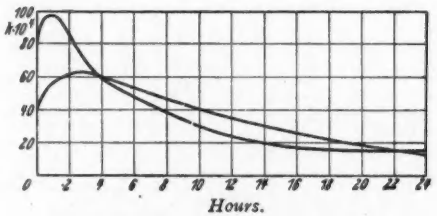

Fig. 40.—Conductivity of Blastfurnace Slag.

difference in the course of the conductivity curves of Portland and blastfurnace cements is undoubtedly very slight. The occasional description of blastfurnace slag as a "latent hydraulic cement" that only develops its hydraulic properties in combination with Portland cement only begs the question when put forward as an explanation of what is as yet an unexplained fact. It is possible that a more comprehensive investigation into the electrical conductivity of blastfurnace slag will throw light upon this complicated question, and work to this end is at present in progress.

The author's electrical conductivity measurements have shown certain important characteristics in the curves for setting cement that Gessner failed to observe. Further, Shimizu's measurements were not confirmed in the case of the slags used in the experiments here described. There is always the possibility, however, that a more reactive, "opened up" slag, giving more rapid gel formation, might show the type of curve obtained by Shimizu. Again, the Portland cement investigated by Shimizu gave a much flatter curve than those found by the author, but this probably depends on the composition of the cement used. Since neither Gessner nor Shimizu published analyses of their cements it is, unfortunately, impossible to offer judgment on these points.

(To be continued.)

Company Meeting.

The Associated Portland Cement Manufacturers, Ltd.

The Thirty-fourth Ordinary General Meeting of the Associated Portland Cement Manufacturers, Ltd., was held on March 31st. Mr. P. Malcolm Stewart (chairman) presided, and in the course of his speech said the profit on trading at £758,724 showed an increase of £90,338, but a full year's profits were included in respect of the businesses acquired in 1931, whereas in that year only six months of such profits were brought in. Interest and dividends on investments at £317,976 showed a reduction of £37,646, due mainly to decreased returns from the cement companies in which they were interested overseas. The world-wide depression had adversely affected cement companies operating abroad, and they must continue to expect diminished returns on these investments until there was a general improvement in trading conditions.

The total revenue for the year was £1,077,451, an increase of £52,739, and they were able, after meeting Debenture stock interest and providing £467,482 for depreciation reserves and Debenture stock sinking funds and the payment of the dividend amounting to £137,500 on the 5½% Preference share capital, to recommend payment of a dividend of 7% on the 3,500,000 Ordinary shares. This would absorb £245,000 and leave a balance of £3,300 to be added to the carry-forward, which would then stand at £166,728.

The Check to New Building.

The Chairman continued: During the past year we experienced two outstanding difficulties. There was the definite check sustained by building operations owing to the action of the Government in curtailing public expenditure by local authorities. However necessary it may have been, this action affected most seriously the building and construction trades, which offer such a high degree of employment. It has been calculated that 80 per cent. of expenditure on building and construction goes directly or indirectly in wages. Unemployment has hit every class, professional men, contractors, operatives, as well as manufacturers of building materials. The considerable interests purchased some two years ago afforded an enhanced opportunity of securing stable prices on a reasonable basis. This opportunity we extended to all manufacturers in our endeavour to secure a fair measure of prosperity for the industry as a whole.

Some manufacturers supported us and, further, were prepared to join in giving important guarantees, an earnest of a sincere endeavour to procure success. However, others took advantage of the situation to fill their order books, so that these efforts ultimately failed. The loss of turnover, accentuated by a falling market, became too heavy. In the export market we were able fairly well to maintain our turnover at the previous year's reduced level, but the tonnage was 48 per cent. below that of 1930. This relatively satisfactory result will be better appreciated when I tell you that while the tonnage of cement exported from the United Kingdom decreased 7.2 per cent. the world decrease was 19.3 per cent., Belgium 31.5 per cent., Yugoslavia 25.5 per cent., Germany 46 per cent., France 8.8 per cent., and America 14.2 per cent. We shipped during the year our well-established brands of Portland cement to 107 countries through 337 ports all over the world.

The trading results achieved could not have been obtained but for the reduction again effected in the costs of production, procured through the past heavy expenditure on factory reconstruction and mechanisation.

Mechanisation.

There is a tendency to condemn mechanisation, which is often a part of the process of rationalisation, because it has contributed to unemployment. This is wrong; the fault lies in our failure to take adequate advantage of the benefits which mechanical science and invention have placed at our disposal. Mechanisation has amazingly increased productive capacity, but this result has been attained with such rapidity that we have outstripped our slow-growing knowledge of how fully to use it. An outstanding success has been scored in that it has transformed much of the most arduous and dangerous manual work, often ill-paid, into easier, safer work, generally better paid. Thus we see that, while mechanisation has been a factor in producing unemployment, it has improved the lot of many remaining employed.

The lower costs obtained benefited the producer, but in a diminishing degree as his products flooded the markets. Lower prices favoured the consumer, but they reacted on the producer. Unemployment and reduced purchasing power became general, whether caused by over-production or under-consumption. I hope the time is not far distant when this country will take the lead in demonstrating that mechanisation need not enslave man, but give him greater freedom, but it need not mould him into a mechanical robot, but enable him to live nearer to nature, and that instead of being his master and bringing misery

it can, if made his servant, bring increased health and happiness through the gift of shorter working hours.

Working Hours.

While politicians and economists are wrestling with the overriding problems designed to bring back the world from a state of chaos to order and make it a more agreeable place to live in, let industrialists plan a scheme of shorter working hours in order to make their contribution to the solution of unemployment, the most pressing problem of the day, and endeavour to promote a closer co-operation with labour; co-operation is as essential to industry as lubrication to machinery. How can industrialists seek to reduce unemployment? Surely by working shorter hours and employing more men. We should not wait for international agreements, which may be long delayed. There are favourable conditions enjoyed by labour in this country which some of our Continental neighbours do not possess, and with regard to which we did not consult them. In this matter I believe we can set our own standard of progress and should take the risk of facing the difficulties in order to accomplish the all-important task of bringing more men back to work.

Initially the costs of production would be somewhat increased, but I am convinced the advantages to industry from the resulting improved efficiency, particularly where the working hours could be condensed into a five working-day week, and from decreased unemployment, would go far to mitigate the increase of costs once experience is gained.

How are we to set to work? In the first place, let industrialists approach the trade unions and say to them: "Will you co-operate with us in an effort to reduce the number of unemployed? Our proposal is to put more men into employment by shortening the hours of work. We want to negotiate with you as to how the cost incurred should be apportioned."

Co-partnership.

Why should we not extend our outlook and offer our employees a partnership in industry, a share in the profits which they have helped to create, also the enjoyment of an annual holiday with pay? Why differentiate between the man with a black coat and the man who takes off his coat to work? Let us abolish these undesirable distinctions. Are these things practical? I believe them to be. A number of manufacturers have set the example. Companies in which I am interested with capital of a market value of over £20,000,000 have also done so to a modest degree. Not one of us would retrace his steps.

Government and Industry.

The present Government has freely consulted industrialists, but has not the time come when the relations between Government and industry should be put on a more permanent footing? The first step I would suggest should be taken is the co-ordination of Government interest in industry. This could be achieved by the appointment of a Minister of Industry; under him could be formed Departments with responsible political chiefs, each to deal with one or more industries, such Departments to be in substitution of existing Ministries and offices dealing with industrial matters. To each could be attached an advisory council, small in number, comprised of industrialists and labour representatives nominated by their respective interests but appointed by the Minister. Then, in addition, there would be needed a general advisory council similarly composed and appointed. Its functions would be to co-ordinate the work of the departmental advisory councils and advise the Minister when called upon on matters of broad policy. To all councils should be attached permanent officials, whose experience and knowledge would be invaluable. Some such scheme is required if Government is to reap the advantage of business experience and obtain ordered results from its interest and influence in industry.

The Outlook.

With regard to the prospects for the current year, it is difficult to make a forecast, in view of the many uncertain conditions affecting our wide trading operations. There is undoubtedly a definite improvement this year in smaller building operations. This may be the forerunner of a more general improvement. It is to be hoped that the Government will hasten to take action, since a sympathetic attitude will not of itself reduce unemployment. On the other hand, it must be realised that the improvement in the smaller building operations is quite insufficient to give rise to a demand which will employ a satisfactory proportion of our production capacity. To accomplish this there must also be a good demand from larger construction work; so far there is but little evidence of this being forthcoming. Then it must be realised that the home trade selling prices are lower, and that this position, unfortunately, coincides with less favourable prospects for our overseas investments. A general improvement of trade at home and a lift of the world depression would mitigate these factors, but time will be required for this to take effect. Therefore the prospects, as I foresee them to-day, hardly warrant the expectation of the maintenance of the results achieved last year.

Chalk and Limestone Screening Plant.

It is well known that the behaviour of lime kilns is adversely affected by the presence of areas of fine material which cause uneven distribution of the heat, so that it is important to remove the fines from the material before feeding it to the kiln. In summer the fine material is dry and easily screened, and a screen with small apertures does the work efficiently. In wet seasons the material

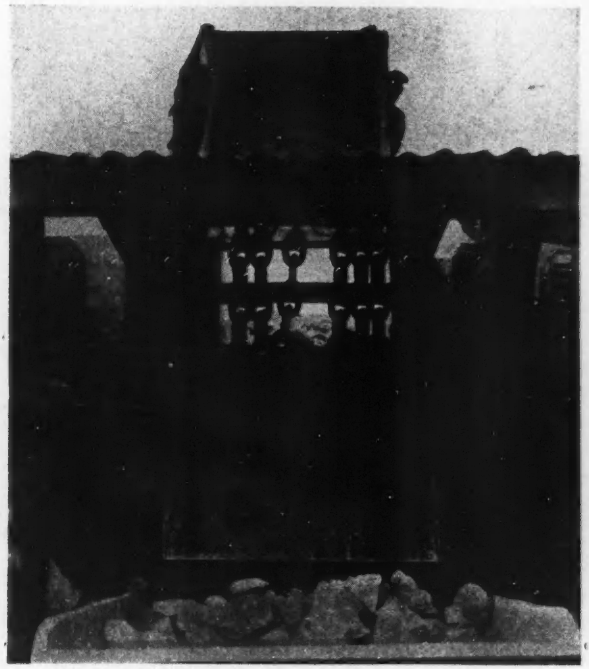

Fig. 1.

packs together in wet lumps, and much larger apertures are required in order to remove the smaller wet lumps of fine material. The screen must at the same time be capable of breaking up the larger lumps of wet fines.

When introducing a new high-capacity power shovel, the Oxted Lime Co., Ltd., of Oxted, Surrey, after careful consideration of the problem of screening, decided to install a Ross roll screen, and this screen has so successfully solved the problem dealing with the varying conditions, that a description of it will be of practical interest.

Fig. 2.

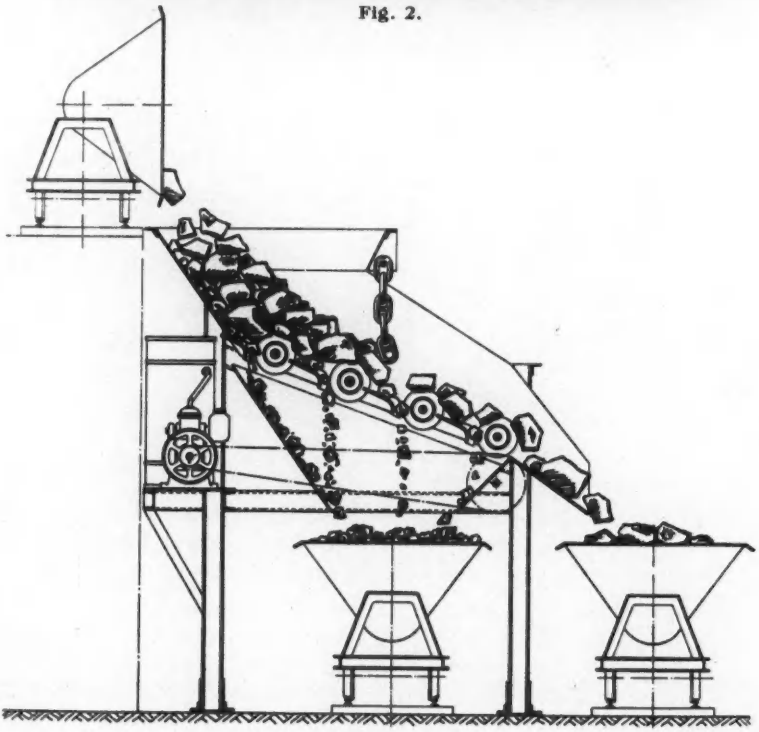

Fig. 3.

The photographs (Figs. 1 and 2) show the Ross roll screen at the works of the Oxted Lime Co., Ltd. A train of one-yard wagons arrives at the tip and the material is dumped on the screen at the rate of sixty wagon loads per hour. The fine and the oversize materials are discharged into similar one-yard trucks running on two parallel tracks, which are 11ft. below the upper track level.

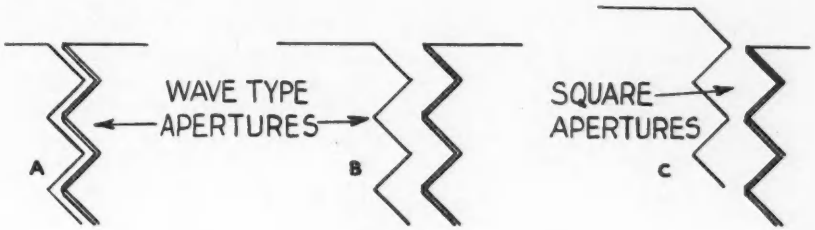

Fig. 4.

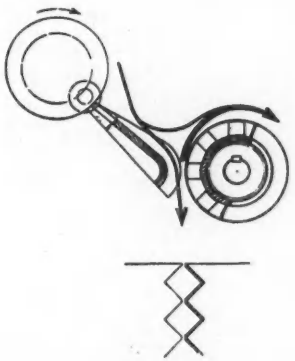

Fig. 5.

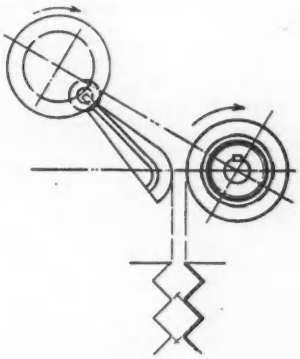

Fig. 6.

Fig. 3 is a section through the screen. Points of importance are that the receiving hopper has steep walls upon which sticky material cannot lodge, and the dumped material makes direct contact with the first two screen rolls. The roll speeds are 20, 30, 40 and 50 revolutions per minute respectively starting from the feed end. The screen is driven by a 3-h.p. oil engine running at 700 revolutions per minute, and the plant is mounted on wheels so that it can be easily hauled to other positions. The screen is 48in. wide.

At this plant the aperture can be varied from ½in. as shown at A on Fig. 4 to 2in. as shown at B. This is done by turning an adjusting screw, an operation which takes less than a minute and which may be carried out while the screen is in operation or at rest. By altering sideways the position of the rear stationary members of the screen in relation to the rolls—an operation which takes about

30 minutes to perform—the apertures can be arranged as shown at C on Fig. 4, the same screw adjustment being used to enlarge these apertures. In this way a clean kiln feed is assured at all seasons of the year.

Figs. 5 and 6 show a section through an aperture of a Ross roll screen. The rear side of the aperture is formed by a smooth-surfaced member over which the material flows with a minimum of friction. The forward side of the aperture is formed by a rotating roll having a serrated or rough surface moving in an upward direction only with relation to the screen apertures. The rear surface promotes swift passage of undersize material and the forward surface promotes quick removal of oversize material. The claim that no jamming or choking of the apertures can occur is substantiated by feeding the screen with broken and twisted scrap metal—a truly drastic test. The Ross roll screen is made by Ross Patents, Ltd., 2, Victoria Street, S.W.1.

Trade Notice.

Pulverising Plant.—A new illustrated catalogue dealing with pulverising plant for firing kilns, steam boilers, and industrial furnaces, and for grinding materials to powder, has been issued by the British Rema Manufacturing Co., Ltd., of Halifax. The catalogue contains a great deal of data relating to the plant described, and much valuable information on considerations affecting the selection of pulverising machines and the operation of such plant. Machines as used in cement manufacture are fully described and illustrated in detail. Copies of the catalogue will be sent on application to those interested.

INDEX TO ADVERTISERS.

Avery, W. & T., Ltd.	—	Metropolitan-Vickers Electrical Co., Ltd.	viii
Babcock & Wilcox, Ltd.	—	"Miag" Mühlenbau und Industrie, A.-G.	iv
British Rema Manufacturing Co., Ltd.	—	New Conveyor Co., Ltd.	xiii
British Thomson-Houston Co., Ltd.	—	Newell, Ernest, & Co., Ltd.	Front Cover
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Davidson & Co., Ltd.	xii	Richter, Oscar A.	—
Davison, Charles, & Co., Ltd.	ix	Rolland, John, & Co.	vii
Fellner & Ziegler	vi	Ross Patents, Ltd.	—
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Glover, W. T., & Co., Ltd.	—	Smidth, F. L., & Co., Ltd.	ii, iii
Helipebe, Ltd.	xiii	Taylor, J. Darnley, & Co., Ltd.	vi
Klöckner-Werke	xiv	Vickers-Armstrongs, Ltd.	x, xi, xiii
Krupp Grusonwerk	vii		